Advanced Numerical Methods for NWP Models

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LONG-TERM GOALS

The long-term goal of this project is to develop a next-generation global atmospheric numerical prediction model that can take advantage of projected computational processing technology to make efficient, high-resolution global modeling a reality. The Navy Spectral Element Atmospheric Model (NSEAM) uses icosahedral grid structures that employ local spectral elements to generate highly accurate and highly scalable global weather forecasts. NSEAM is expected to allow for the Navy to use global models to predict the weather at resolutions of 25 km and less in the coming years.

OBJECTIVES

The objective of this project is to apply state-of-the-art physical parameterizations to NSEAM, develop and test supporting pre-and-post-processing software, and interface NSEAM to a variational analysis, leading to a next-generation global data assimilation and prediction system. While the dynamics of NSEAM continue to be refined in a companion project at the Naval Postgraduate School (NPS), this project integrates the physics and supporting software from the current Navy global atmospheric model, the Navy Operational Global Atmospheric Prediction System (NOGAPS) into NSEAM. Upon the completion of the integration of the NOGAPS physics into NSEAM, NSEAM will be subjected to a variety of idealized and real-data forecast problems to validate it's performance.

APPROACH

Our approach is to perform collaborative work with Dr. Frank Giraldo at the Naval Postgraduate School (NPS) to: (a) merge the dynamic core of NSEAM with the physical parameterizations used in NOGAPS, (b) develop and/or utilize existing pre-, post-processing, and validation software for applications of NSEAM to idealized and real data, and (c) interface NSEAM to the NRL Atmospheric Variational Data Assimilation System-Accelerated Representer (NAVDAS-AR) which will include the development of the NSEAM adjoint and tangent linear models (TLM). This will allow for data assimilation experiments that will lead to validation of the full NSEAM data assimilation and prediction system for operational applications as the next-generation Navy global modeling system.

WORK COMPLETED

The following work was accomplished in FY07:

1. Physics parameterizations from NOGAPS have been successfully implemented into NSEAM similar to the way they are implemented in NOGAPS (Kim et. al. 2006).

Report Documentation Page

1. REPORT DATE **30 SEP 2007**	2. REPORT TYPE **Annual**	3. DATES COVERED **00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE **Advanced Numerical Methods For NWP Models**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Monterey,CA,93943-5502**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

2. The code to generate topography and climatological surface conditions (e.g., orographic standard deviation, surface roughness enhancement terrain, ground wetness) has been developed to interpolate the data for the NSEAM grid.

3. The NSEAM model has been configured in a general way to start with any specification of initial conditions. In our tests, we have run used initial conditions that for aqua-planet, Rossby-Haurwitz waves, and baroclinic jet simulations (Kim et. al. 2006).

4. New functionality has been developed and/or modified in NSEAM for domain decomposition, time interpolation for forcing, Gaussian-grid-to-NSEAM-grid interpolation, spatial diffusion, and restarting capability (Kim et. al. 2007).

6. The model code has been ported to multiple platforms (e.g., SGI, IBM).

RESULTS

Our first set of experiments used were Aqua-planet simulations, which ensure a well-controlled environment (e. g., all-water surface, prescribed initial and boundary conditions, and fixed geophysical and radiation conditions) for model inter-comparisons. Sensitivity tests to improve the equatorial wave propagation speed have been conducted by varying the viscosity for physics, vertical resolution and layer distribution, radiation time step, and boundary conditions, etc. Fig. 1 shows a comparison of simulated convective clouds averaged over the equatorial band (5S-5N) over a 3 month period. The equatorial Kelvin wave, which propagates eastward in time, is well simulated by NSEAM (Fig. 1d) compared with resolved clouds by the high-resolution NICAM global model (Fig. 1a) as well as other leading global models (Figs. 1b and 1c), demonstrating the reasonable coupling between the physics and dynamics of the model.

Tests of NSEAM with idealized initial conditions show reasonable results that are consistent with meteorological theory. With very strong surface heating, initial barotropic Rossby-Haurwitz waves develop into string baroclinic jets and to extra tropical and tropical cyclones (Fig. 2).   Initial perturbations that are superimposed on unstable baroclinic jets are found to grow mush faster with physical parameterizations turned on as opposed to the simulations that did not use the physical parameterizations. Without physics, the growing disturbances exist only at baroclinic zones. With physics, they not only grow faster in the baroclinic zones but also in low latitudes through convective instability. The ratio of computer time consumptions between dry dynamic and physics calculation is about 5:4 to 5:5 for NSEAM with a horizontal resolution of 2.5 degrees.
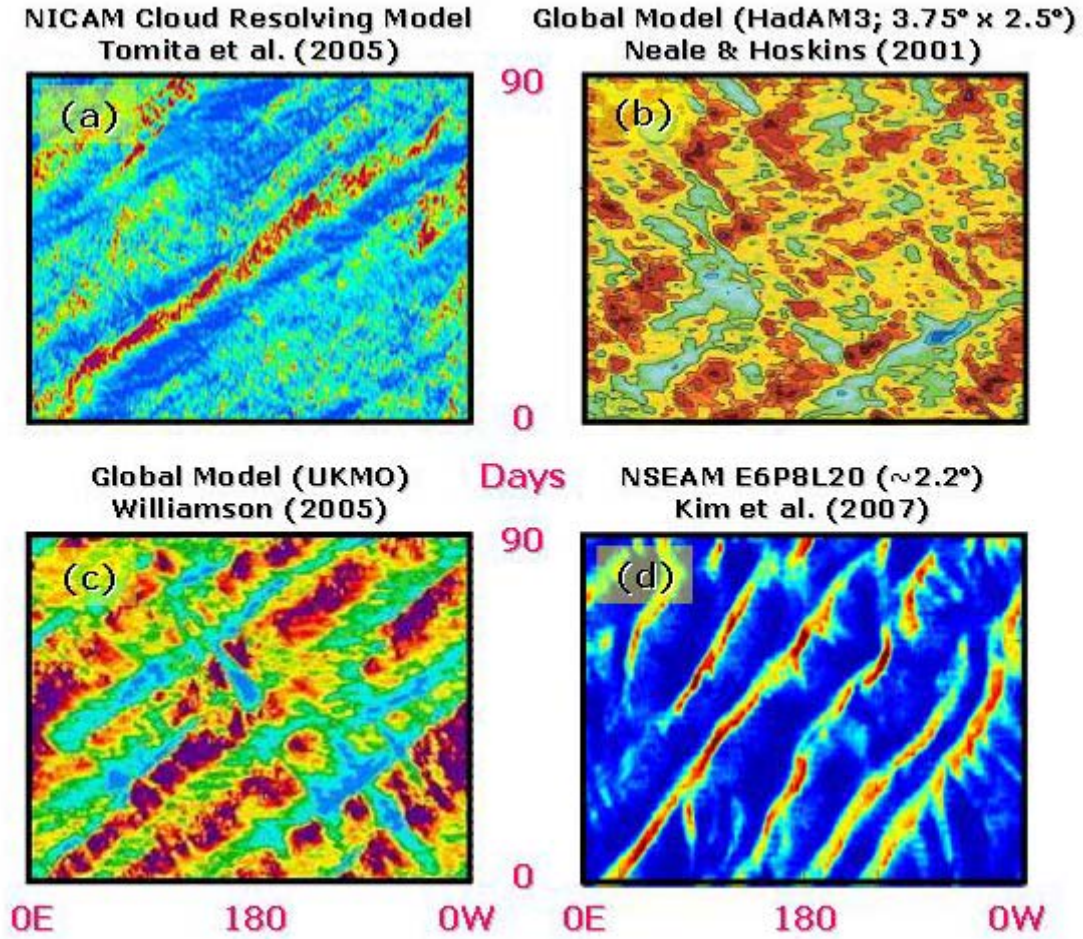
Fig. 1. *Comparison of Aqua-planet simulations for 4 models in terms of simulated convective clouds over the equator (5S – 5N): (a) NICAM cloud-resolving model, (b) HadAM3 model, (c) UKMO global model, and (d) NSEAM. High cloud areas are marked by reddish colors.*
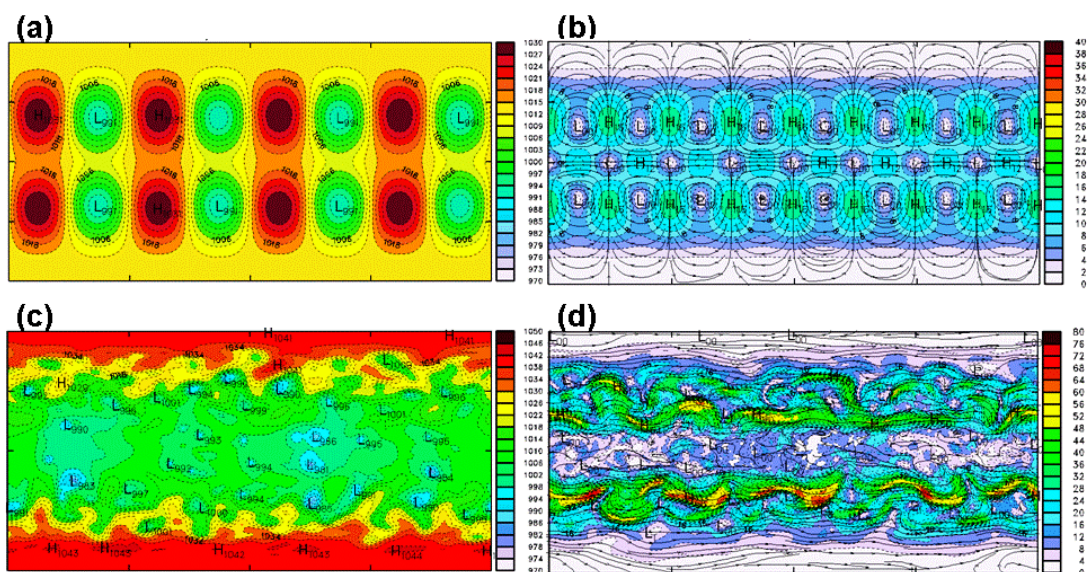
Fig. 2. Test of NSEAM with physics for Rossby-Haurwitz waves: (a) sea level pressure (mb) at initial time, (b) 300 mb wind (m/s) at initial time, (c) sea level pressure after 10 day integration, and (d) 300 mb wind after 10 day integration. The ground surface is ocean between 20^oN and 20^oS and land elsewhere. The ground temperature is 298^oK at equator and decreased to 271^oK at poles by a cosine pattern.

IMPACT

NOGAPS is run operationally by FNMOC and is the heart of the Navy's operational support to nearly all DOD users worldwide. This work targets the next-generation of this system for massively parallel computer architectures. NSEAM has been designed specifically for efficient use of these types of computer architectures while yielding the same high-order accuracy as NOGAPS.

TRANSITIONS

Improved algorithms for model processes will be transitioned to 6.4 (PE 0603207N) as they are ready, and will ultimately be transitioned to FNMOC with future NOGAPS upgrades.

RELATED PROJECTS

Some of the technology developed for this project will be used immediately to improve the current spectral transform formulation of NOGAPS in other NRL projects.

REFERENCES

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